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Influence of plant genotype on mycorrhizal infection: Response of three pea cultivars

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Abstract

Three leafless pea cultivars (JI 1198, BS 142 and BS 4) with the same phenotype and similar patterns of development, were tested in a sterilized low-phosphate soil for their response to phosphate fertilizer and to vesicular-arbuscular mycorrhizal (VAM) infection by three *Glomus* species. Cultivar JI 1198 was very responsive to phosphate but not to inoculation with *Glomus mosseae, Glomus caledonium* or *Glomus epigaeum*. Phosphate and VAM treatments increased growth of cultivar BS 142 but were ineffective with cultivar BS 4.

Fungal infectivity could not be related with endophyte effectiveness at stimulating plant growth, although the percentage of root length infected by each one of the three *Glomus* species did not vary between cultivars. Genetic differences among plant cultivars can thus markedly affect the symbiosis between the host root and VAM fungi; this suggests that potential host-endophyte combinations need to be evaluated before being tested in the field.

Introduction

Some variability in the effectiveness of vesicular-arbuscular mycorrhiza has been widely described between plant species (Baylis, 1975; Owusu-Bennoah and Moss, 1979), within species (Hall, 1978; Nemec 1978) and even within cultivars of the same crop species (Ollivier *et al.*, 1983). Bertheau *et al.* (1980) and Azcón and Ocampo (1981) described the variation in vesicular-arbuscular mycorrhizal (VAM) effectiveness on wheat cultivars grown at different sites and in different seasons, factors that could also account for some of the variability found in VAM behaviour. Little reference has ever been made (Krishna *et al.*, 1985) to the phenotypic or genotypic identity of the plants used as VAM hosts. The purpose of our work was to determine the effects on mycorrhizal dependency and root colonization of three pea cultivars phenotypically identical and grown under the same conditions.

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Material and methods

Three leafless pea (*Pisum sativum* L.) cultivars (BS 4, BS 142 and JI 1198, supplied by the John Innes Institute, Norwich) were used in this experiment. Cultivars BS 4 and BS 142 were near isogenic lines. Seeds were surface-sterilized with 10% NaOCl for 15 mn followed by three 10 mn rinses with sterile distilled water, and pre-germinated for 24 hours at 4°C, before being sown in 10 cm pots filled with 600 g of a sterile soil-sand mixture (1:1), limed to pH 7 with 3 g kg^{-1} $CaCO_3$. The soil from Sawyers Field at Rothamsted (Clark and Mosse, 1981), was γ-irradiated (1 Mrad) and the sand was autoclaved for two separate 1 h periods at 120°C before use. The soil had a low pH (pH 5) and low phosphate content (10 mg kg^{-1} $NaHCO_3$-soluble P.

Olsen *et al.*, 1954). Two pregerminated seeds were sown per pot, thinned to one plant per pot after emergence. Treatments were: non inoculated control, 98 mg P kg^{-1} supplied as $CaHPO_3$, and inoculation with three VAM species. Selected VAM inocula consisted of infective soil from Rothamsted pot cultures of *Glomus mosseae* (> 500 spores g^{-1}), *Glomus caledonium* (> 200 spores g^{-1}) and *Glomus epigaeum* (> 60 spores g^{-1}), all named according to Trappe (1982).

The inoculum, consisting of mycelium, infected root fragments and resting spores, was placed below the seed at 2 g per pot for *G. mosseae* and *G. caledonium* and 4 g per pot for *G. epigaeum*. These amounts were considered saturating and would produce maximum host infection by any of the fungi. Soon after emergence, 1 ml of a *Rhizobium leguminosarum* culture (Rothamsted strain 1045) was added to all pots.

The experimental design was: 3 cultivars × 5 treatments (3 VAM inoculated and 2 controls, as stated before) × 5 replicates.

The 125 pots were randomly distributed on regularly watered sand trays in a greenhouse with no heating or additional lighting, the experiment being conducted in June and July.

Height measurements were recorded on 3,5,6 and 9 week-old plants. Percentage of mycorrhizal root (percent root-length infected) and shoot dry weight were measured at harvest (9 weeks after sowing). The amount of root length infected was assessed on a cleared and stained root sample from each pot (Phillips and Hayman, 1970) using the gridline intersect method (Giovanetti and Mosse, 1980).

Mycorrhizal and phosphorus dependency can be determined by expressing the dry weight of the plants concerned as a percentage of the dry weight of the control plants.

Results and discussion

A factorial ANOVA was used in first instance to analyse the results. There was a significant quantitative interaction ($P < 0.01$), between treatments and pea cultivars, meaning that the three pea cultivars responded differently to VAM inoculation and P fertilization, therefore no treatment could be claimed to be the best. A separate one way ANOVA was then conducted to analyse the behaviour of each cultivar separately. The final values (average of five replicates) for shoot height, dry weight and percentage root length infected are shown in Table 1.

Response to phosphate fertilizer is usually positively correlated with response to VAM inoculation (Ollivier *et al.*, 1983). This was so for cultivars BS 4 and BS 142. Although both cultivars belonged to near isogenic lines, BS 4 responded neither to P nor to VAM inoculation ($P < 0.01$) while BS 142 responded to both, eventhough P fertilisation was more effective than VAM treatments.

Cultivar JI 1198 responded to phosphorus but not to VAM inoculation with any endophyte used ($P < 0.01$). Hall (1978) found a maize cultivar (Px 610) which behaved similarly and attributed this to the plant's intrinsec ability to absorb P (Clark, 1983; Nielsen and Schjørring, 1983).

Cultivar JI 1198 outgrew BS 142 in the control treatment without added P, BS 142 showed a high mycorrhizal dependency, with significant responses to all VAM treatments ($P < 0.01$) and also a higher P dependency than JI 1198.

Although these results show that mycorrhizal effectiveness at improving plant growth varies with host-plant genotype, the infectivity of VAM fungi used in our experiment remained the same, irrespective of the host plant cultivar. The percentage of mycorrhizal root varied between the different fungal species but not between plant cultivars. *Glomus mosseae* produced the highest amount of internal infection in all cases, above 70%. There was no significant differences between *G. mosseae* and *G. caledonium* in stimulating plant growth in cultivar BS 142 ($P < 0.01$), the only cultivar that responded consistently to VAM inoculation. *Glomus epigaeum* was the least infective and least effective ($P < 0.05$) at enhancing plant growth under our experimental conditions. Ollivier *et al.* (1983) had similar results with another legume, *Vigna unguiculata*. Hayman and Tavares (1985) however, found that *G. epigaeum* was the most effective fungal species at enhancing the growth of strawberry plants in Sawyers soil at pH 7 and produced a very high percentage of root length infected (above 90%).

Therefore a certain degree of host-specificity in VAM symbiosis should be taken into account while evaluating potential field inoculations.

Table 1. Shoot length, dry weight and mycorrhizal infection, of three pea cultivars, VAM inoculated, uninoculated and amended with phosphorus

Treatment	Cultivars								
	JI 1198			BS 4			BS 142		
	Shoot length (cm)	Dry weight (g)	% infected root	Shoot length (cm)	Dry weight (g)	% infected root	Shoot length (cm)	Dry weight (g)	% infected root
Control 0	43 ± 4	0.89 ± 9.10	0	40 ± 2	1.01 ± 0.05	0	28 ± 7	28 ± 7	0.61 ± 0.16
Glomus mosseae	42 ± 5	0.87 ± 0.11	81 ± 6	46 ± 3	1.17 ± 0.08	70 ± 6	53 ± 6	1.16 ± 0.14	75 ± 6
Glomus caledonium	43 ± 5	0.89 ± 0.11	63 ± 3	43 ± 1	1.10 ± 0.03	45 ± 16	49 ± 2	1.07 ± 0.05	56 ± 10
Glomus epigaeum	41 ± 6	0.86 ± 0.14	30 ± 17	33 ± 9	0.85 ± 0.25	47 ± 20	41 ± 4	0.90 ± 0.10	28 ± 9
98 mg P kg^{-1}	62 ± 11	1.27 ± 0.23	0	44 ± 4	1.13 ± 0.11	0	64 ± 3	1.41 ± 0.07	0
LSD 0.05	9.3	0.19		6.7	0.19		6.7	0.13	
LSD 0.01	12.6	0.25		9.1	0.25		9.1	0.18	

Standard errors of mean are given. Each figure is the mean for five replicates.

Conclusions

Our data show a clear influence of host-plant genotype on the effectiveness of VAM symbiosis, which can account for apparently conflicting experimental results even when genetically-related cultivars with similar phenotypes, are used as host plants for VAM performance studies. This suggests that plant cultivars bred for different purposes should be tested under defined experimental conditions before being tested in the field.

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